

Multilayer collector mirror for DPP EUV metrology sources

2014 International Workshop on EUV and Soft X-ray
Sources

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optiX fab.

Outline

- Introduction
- Some recent EUV optics activities
- Elliptical off-axis metal mirror for DPP EUV metrology sources
- Summary and acknowledgement

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optiX fab organization

- **Mission:** Fabrication of customized EUV optics and optical components for EUV lithography @ 13.5 nm and beyond, synchrotron and FEL beamlines, metrology, R&D applications, etc.
- **Foundation:** Dec 2012, fully operational: August 1, 2013
- **Address:** optiX fab GmbH
Hans-Knöll-Str. 6
D - 07745 Jena
- **Email:** info@optixfab.com
- **Production:** Delivery of > 3000 soft X-ray and EUV multilayer mirrors since Aug 1, 2013

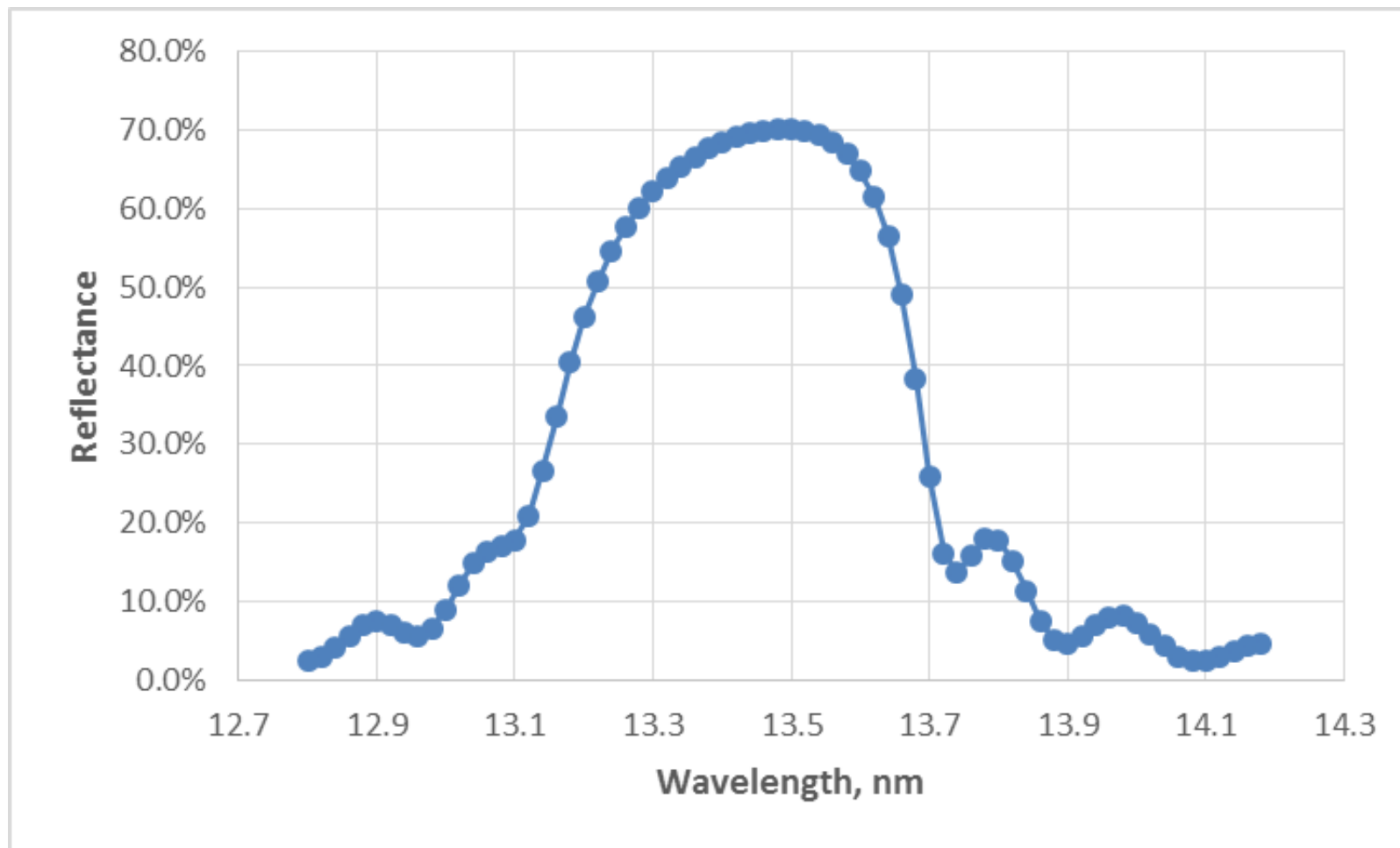
- **Team:**



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Multilayers for 13.5 nm



R = 70.12 %

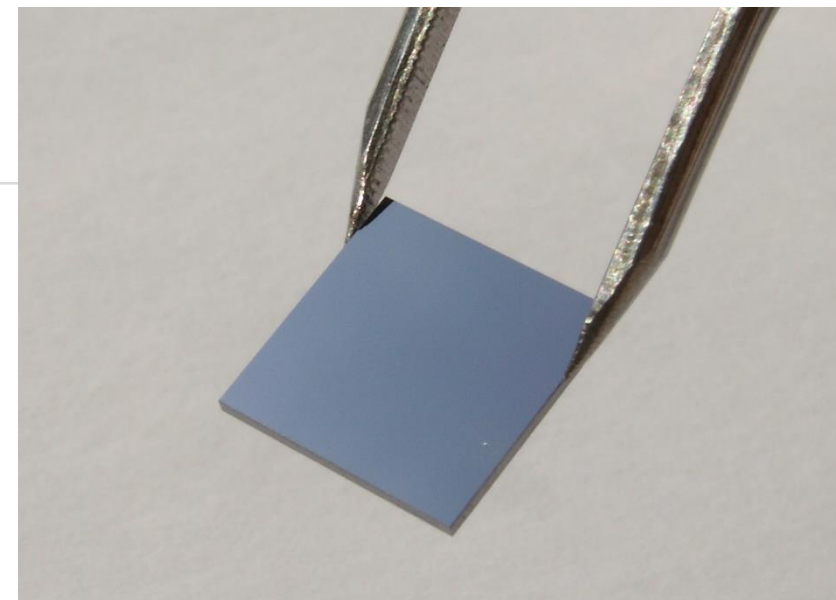
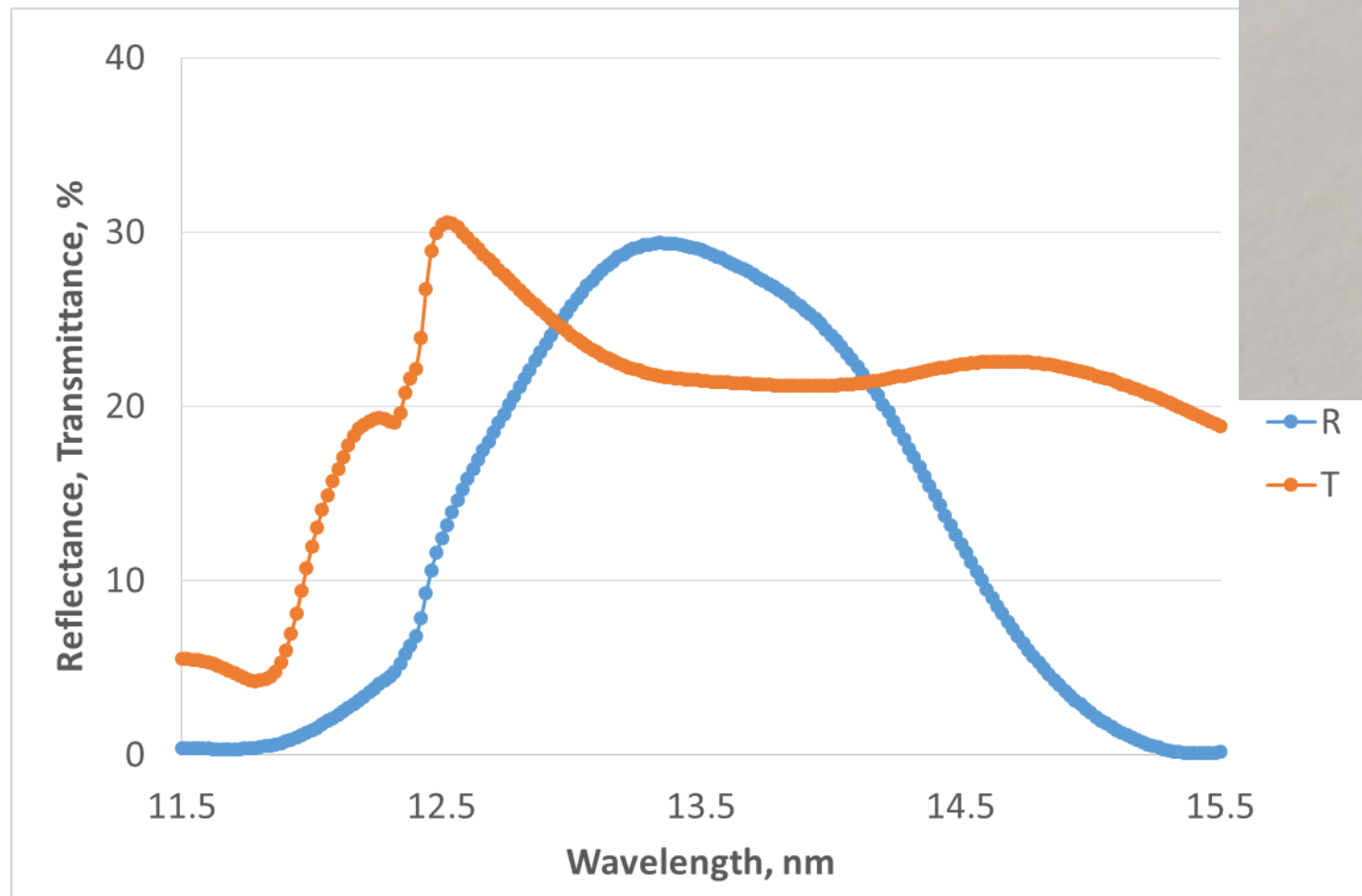
$\lambda = 13.49$ nm

FWHM = 0.521 nm

AOI = 5 deg.

Measured @PTB Berlin

Beamsplitters for 13.5 nm



R = 29.0 %

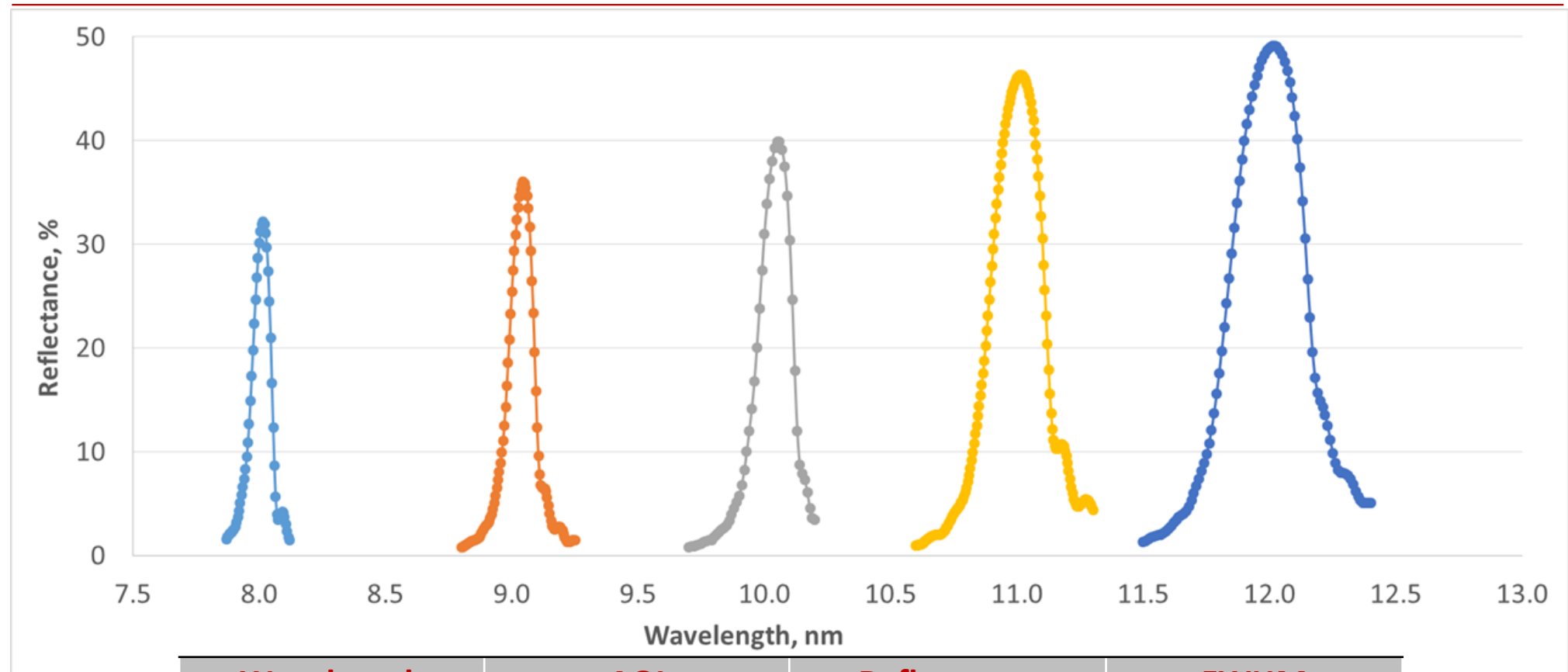
T = 21.5 %

$\lambda = 13.5 \text{ nm}$

AOI = 45 deg.

Measured @PTB Berlin

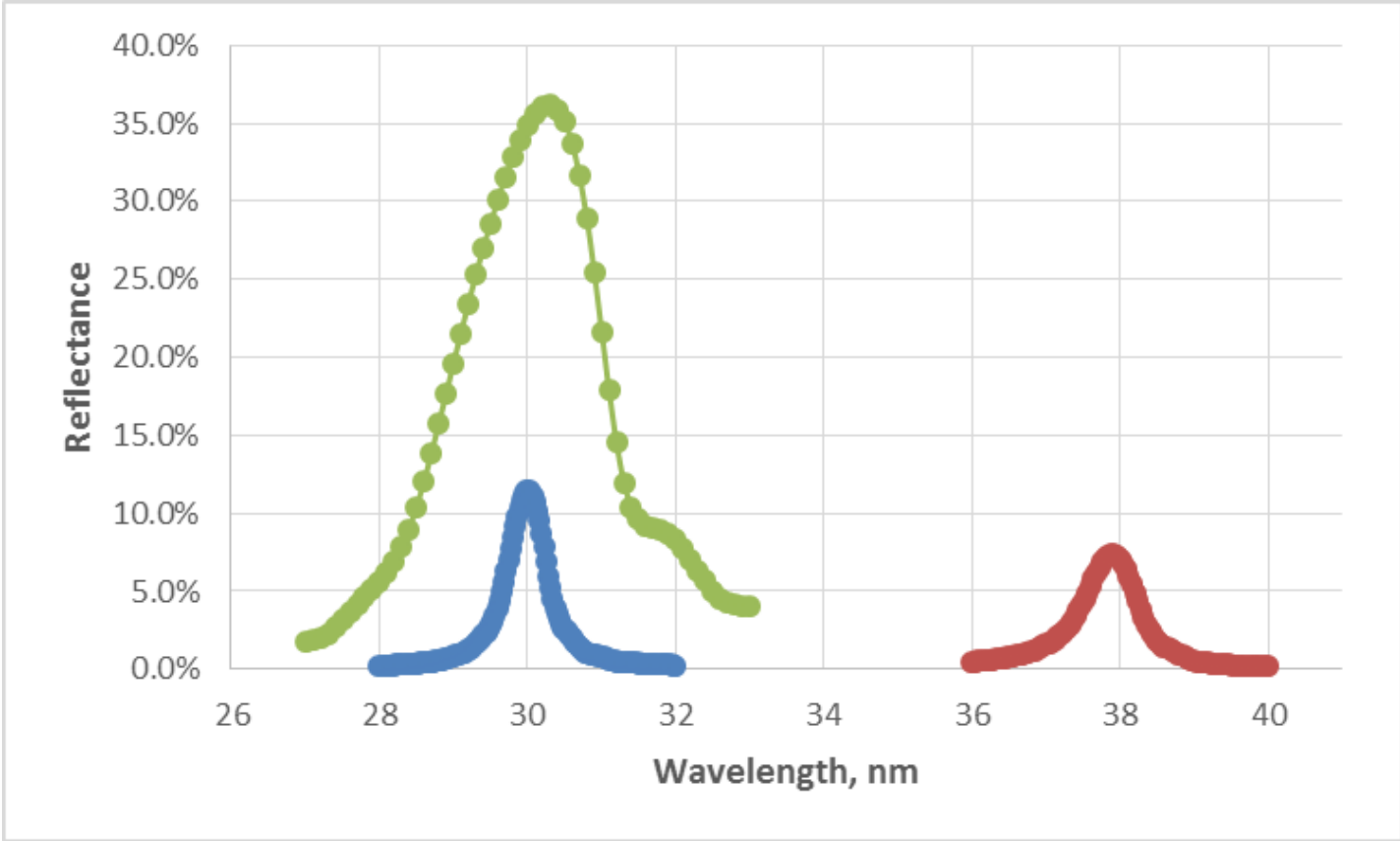
Multilayers for 8 ... 12 nm



Wavelength	AOI	Reflectance	FWHM
8.0 nm	5 deg	32.2 %	0.08 nm
9.0 nm	5 deg	36.0 %	0.11 nm
10.0 nm	5 deg	39.9 %	0.15 nm
11.0 nm	5 deg	46.3 %	0.23 nm
12.0 nm	5 deg	49.1 %	0.33 nm

Measured
@PTB Berlin

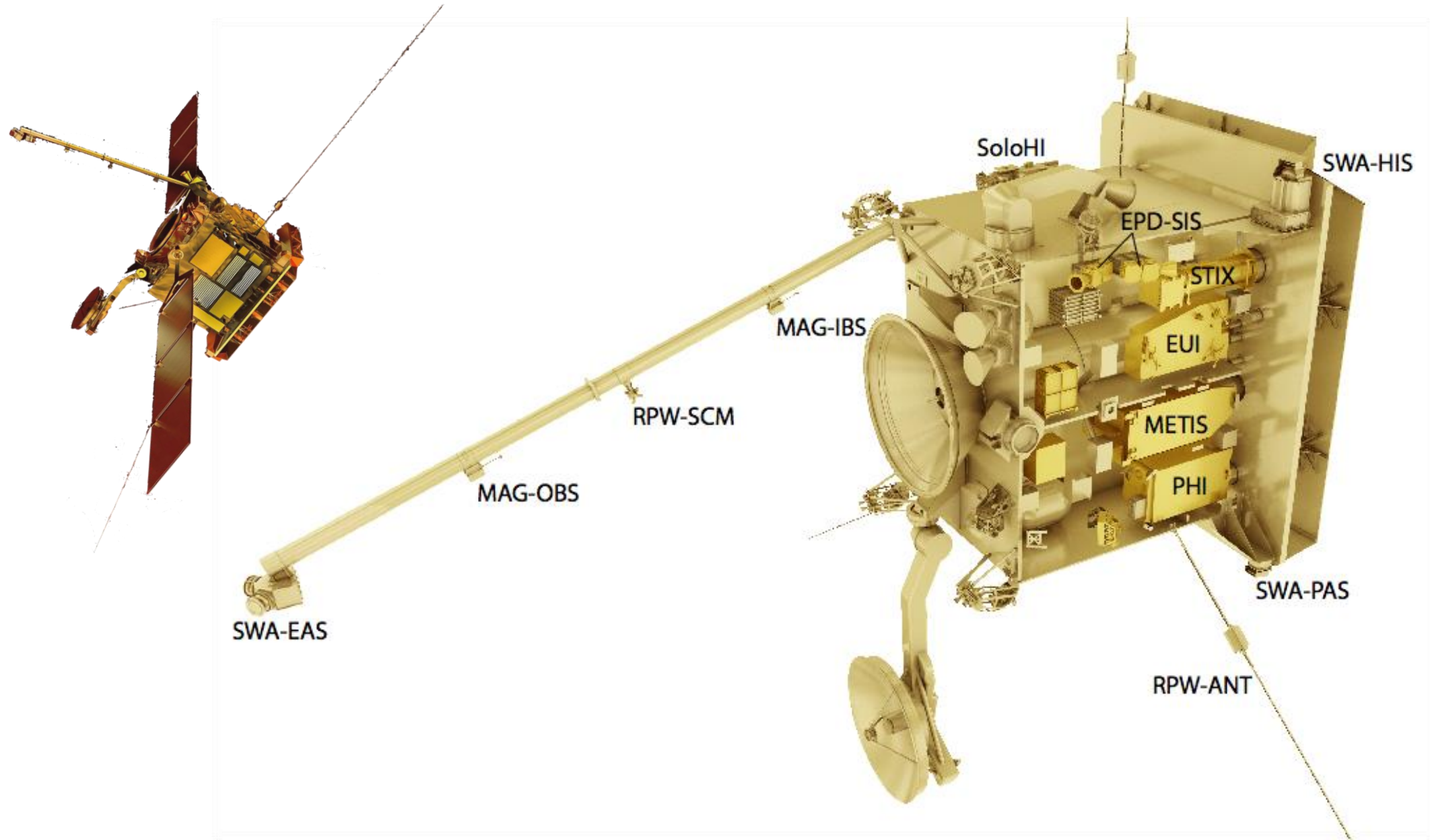
Narrowband Multilayers for 30 ... 38 nm



Wavelength	AOI	Reflectance	FWHM	ML Design
30.0 nm	5 deg	36.1 %	2.17 nm	
30.0 nm	15 deg	11.5 %	0.60 nm	narrow band
38.0 nm	15 deg	7.4 %	0.86 nm	narrow band

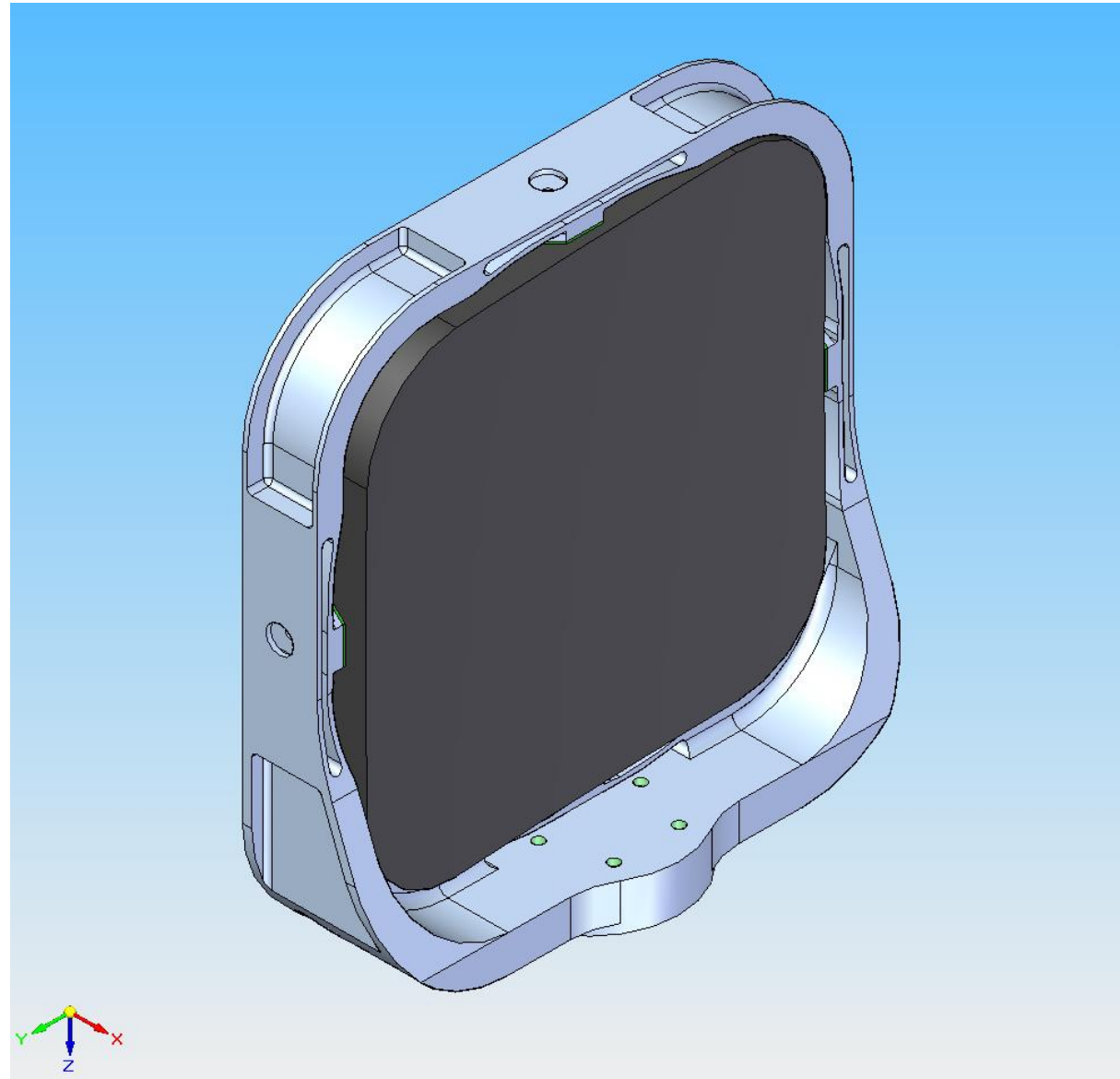
Measured
@PTB Berlin

SPICE primary mirror and coating of grating for Solar Orbiter



SPICE primary mirror for VUV Spectrograph

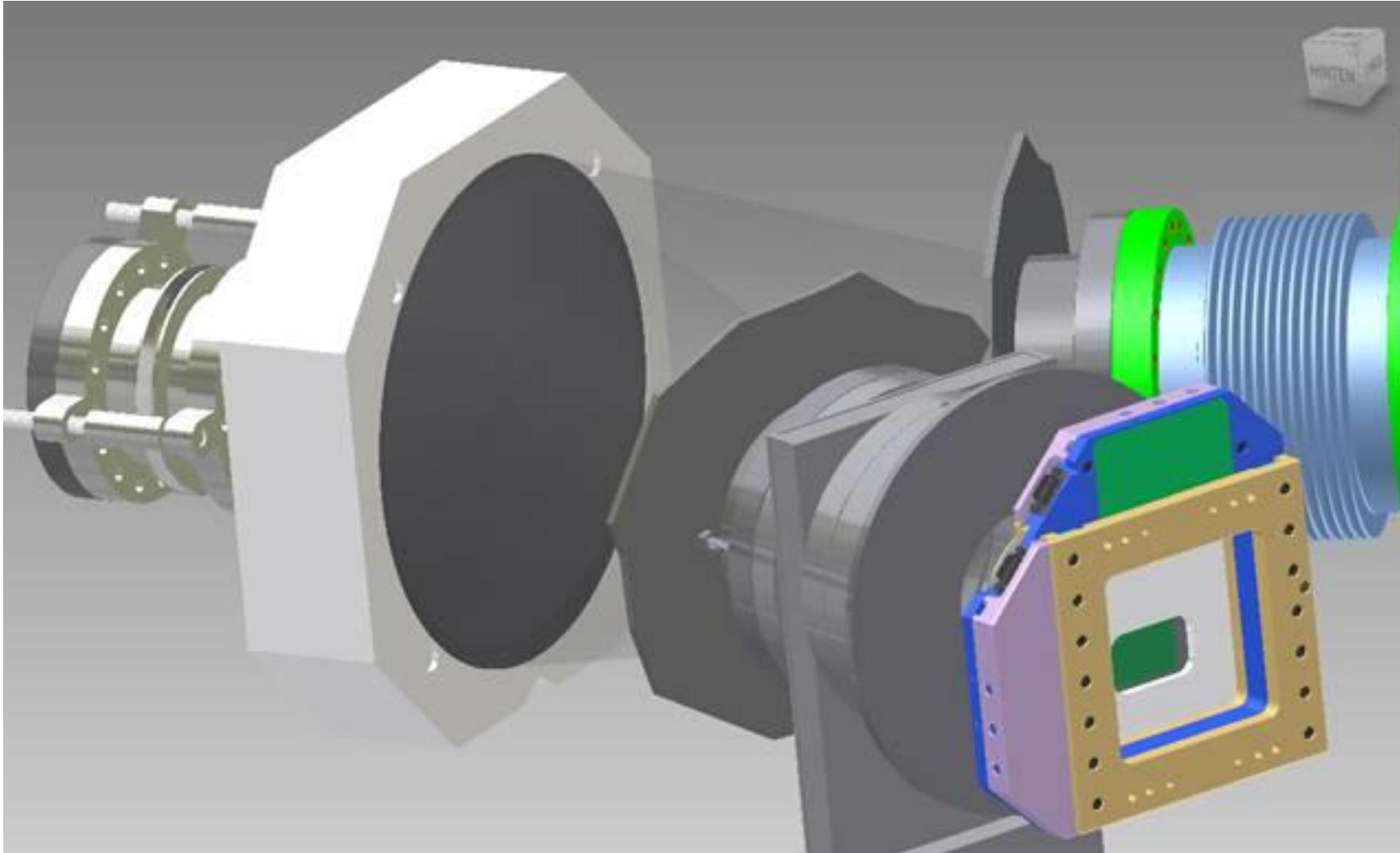
- Parabolic off-axis mirror
- $f = 633 \text{ mm}$
- $103 \text{ mm} \times 103 \text{ mm}$
- fused silica
- $\text{HR } \lambda_1 = 70.2 - 79.2 \text{ nm}$
- $\text{HR } \lambda_1 = 97.0 - 105.0 \text{ nm}$
- Backside AR 550 nm
- form error $< \lambda / 20$
- HSF roughness $< 0.2 \text{ nm rms}$



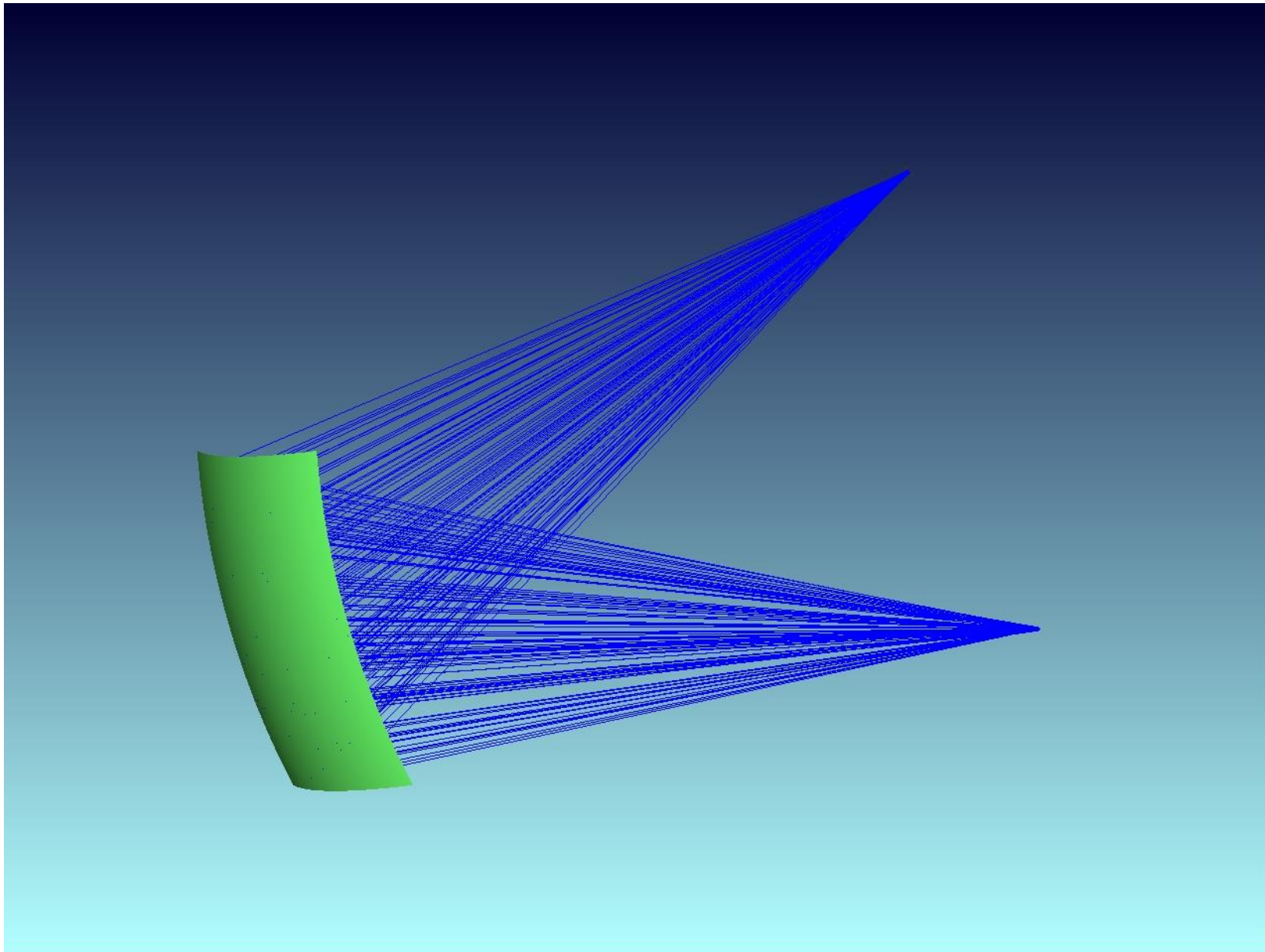
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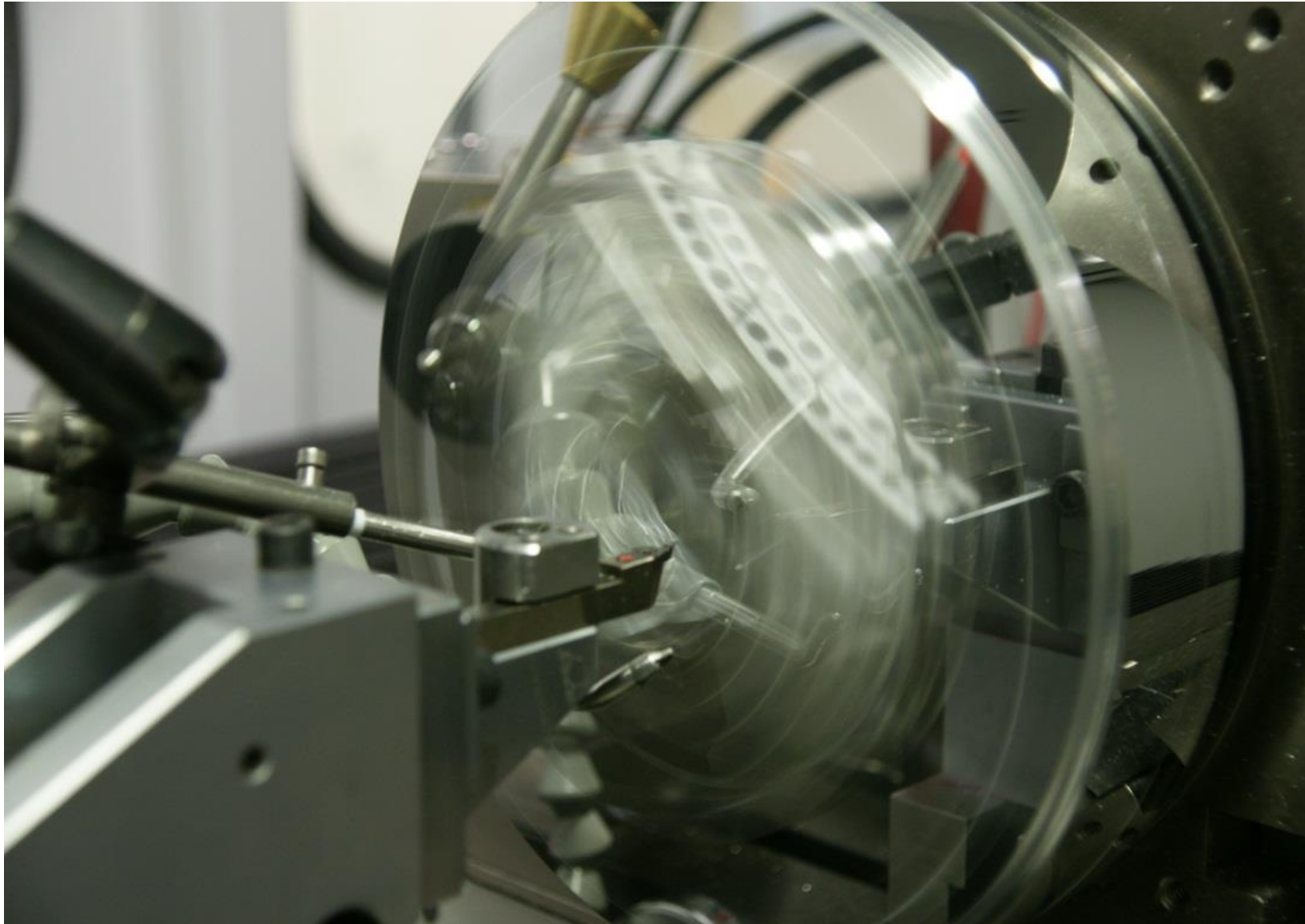
EUV Source Collector Module



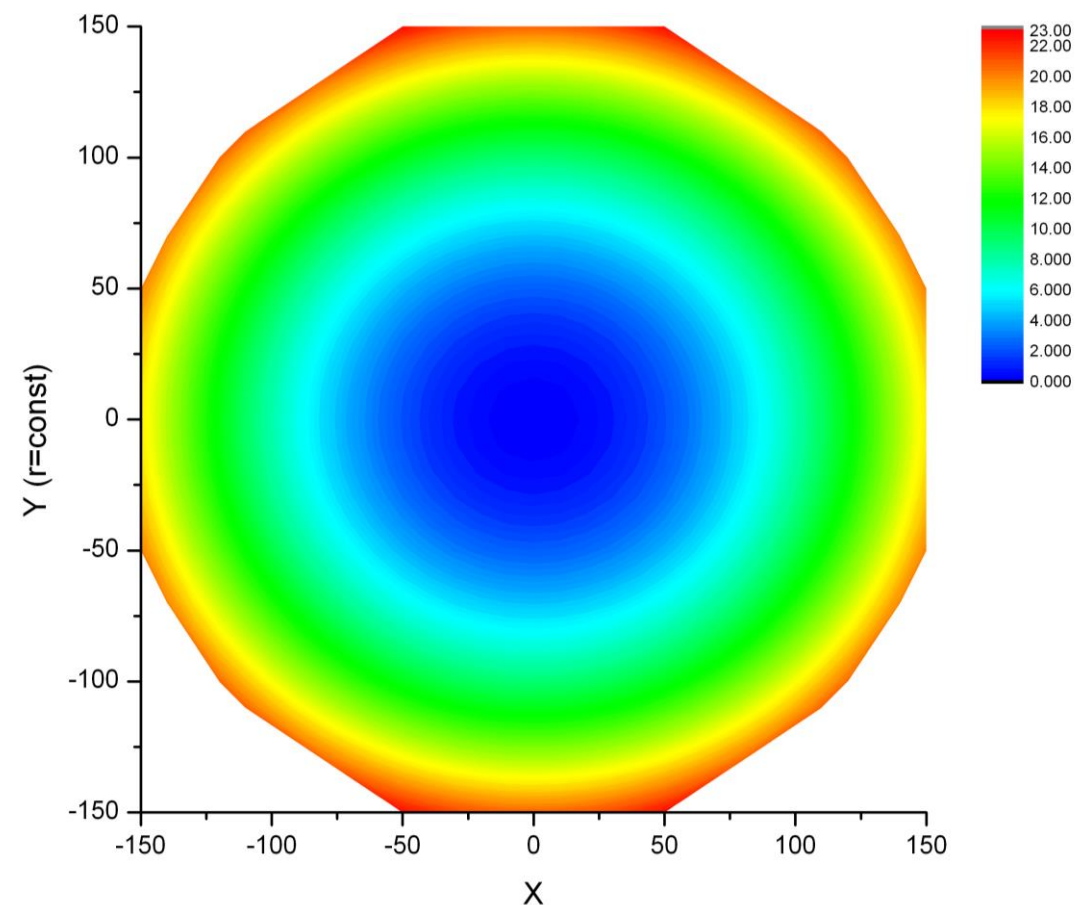
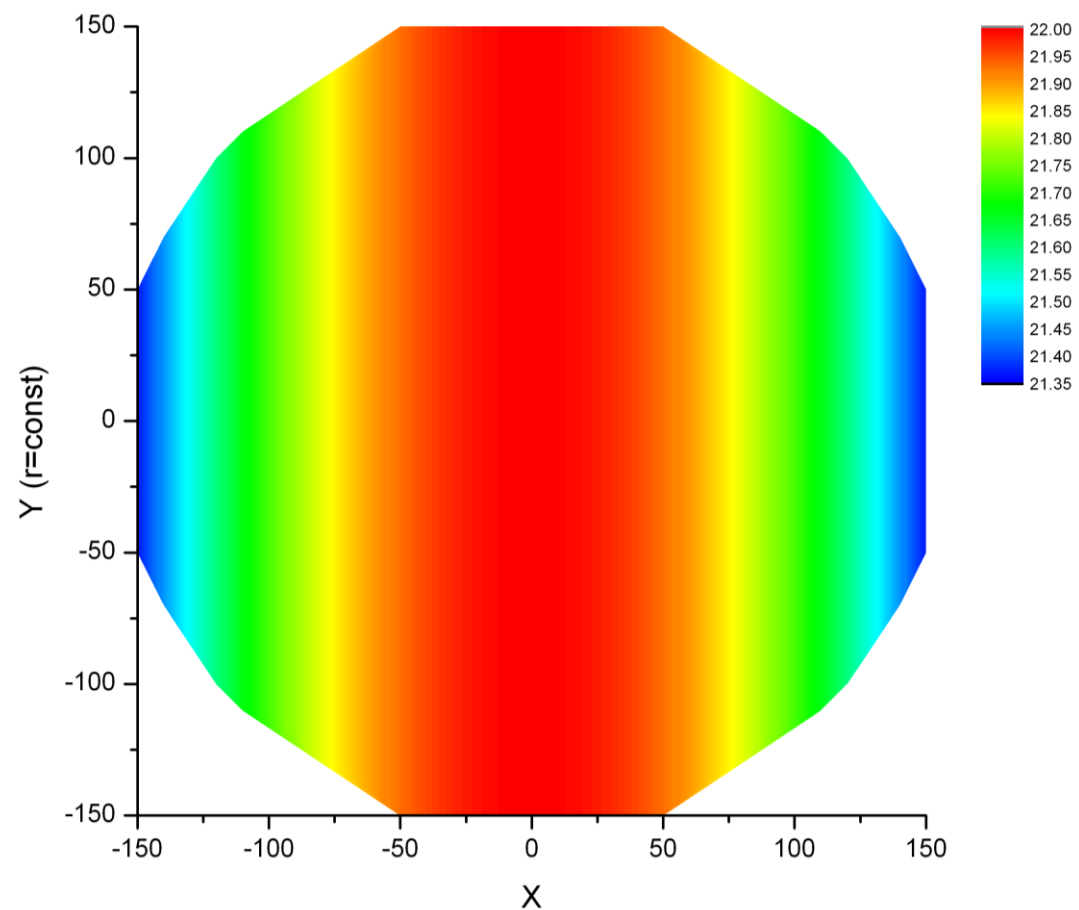
3D model of beam path



Off-axis elliptical metal mirror fabrication: diamond turning

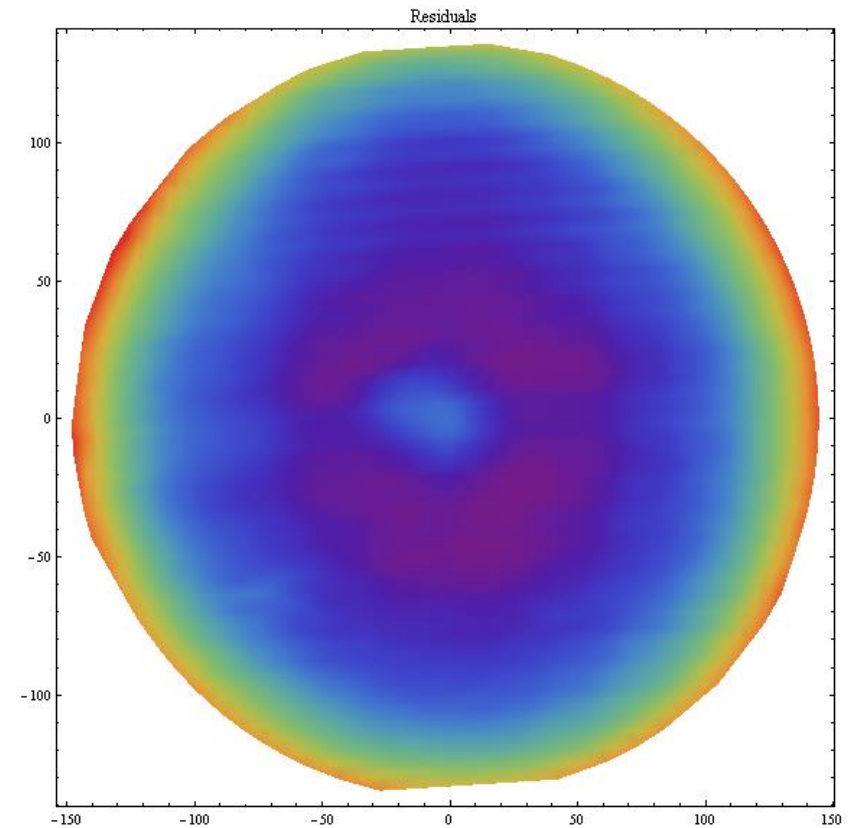
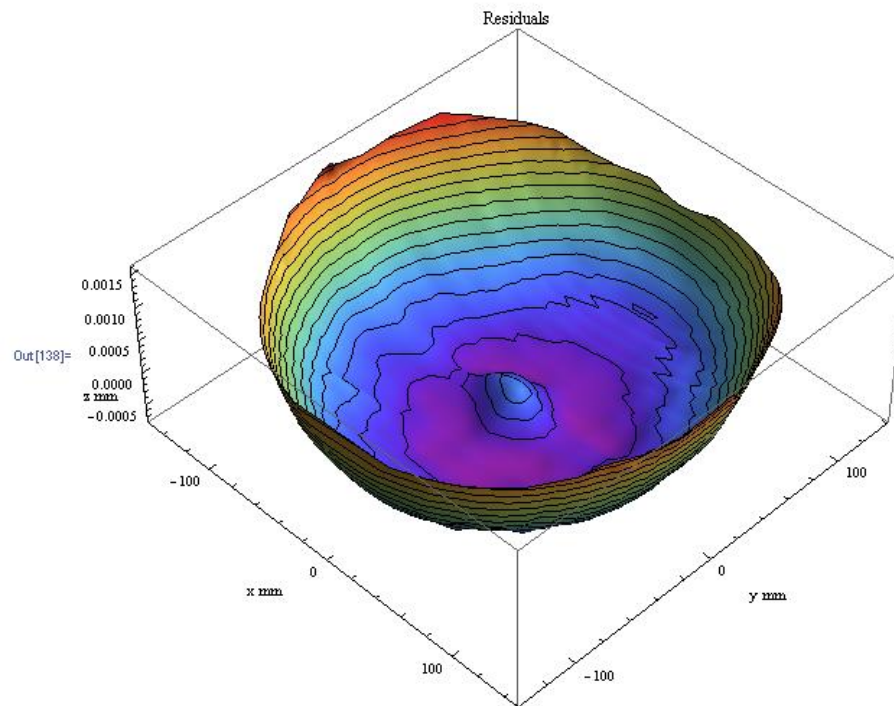


AOI Distribution and mirror sag



Substrate form characterization

```
a = 600; (*Semi Major Axis - Rotation Axis*)  
b = 556.31; (*Semi Minor Axis - Rotation Radius*)  
r = a^2 / b;  
c = 1 / r;
```

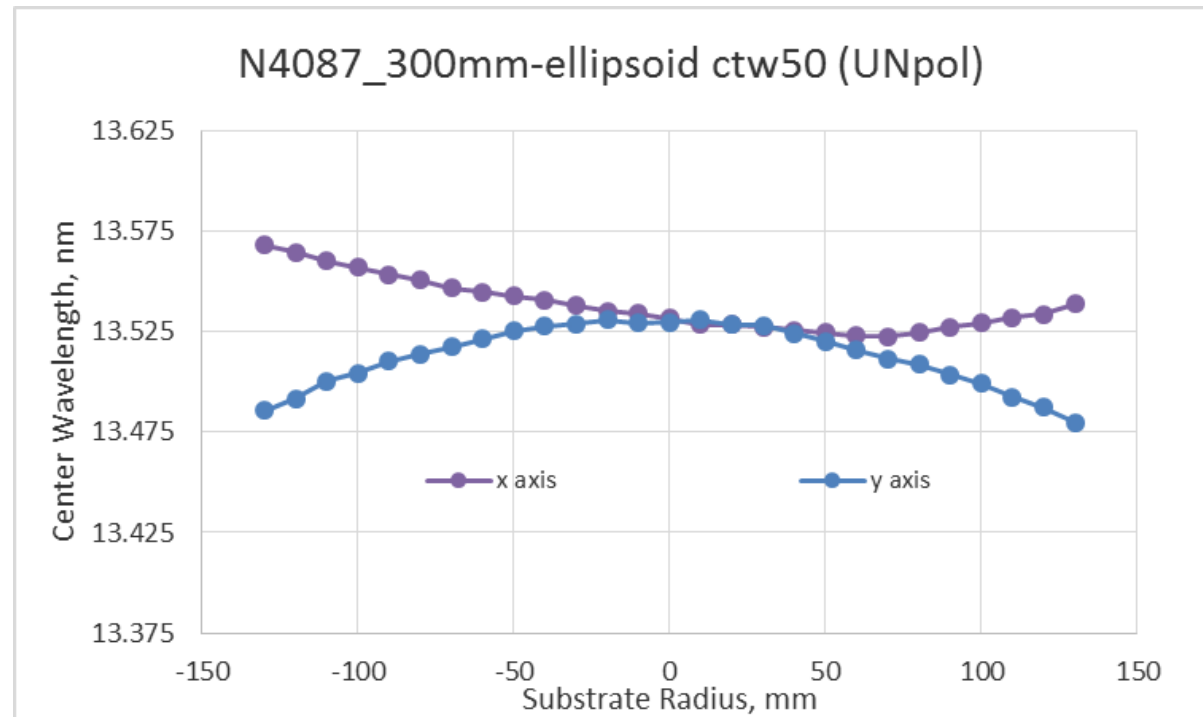


```
Out[139] Z Werte Statistik:  
0.558 µm rms,      2.313 µm pv,  
1.579 µm Max,     -0.734 µm Min
```

Characterization of reflective properties

Center wavelength (unpolarized)

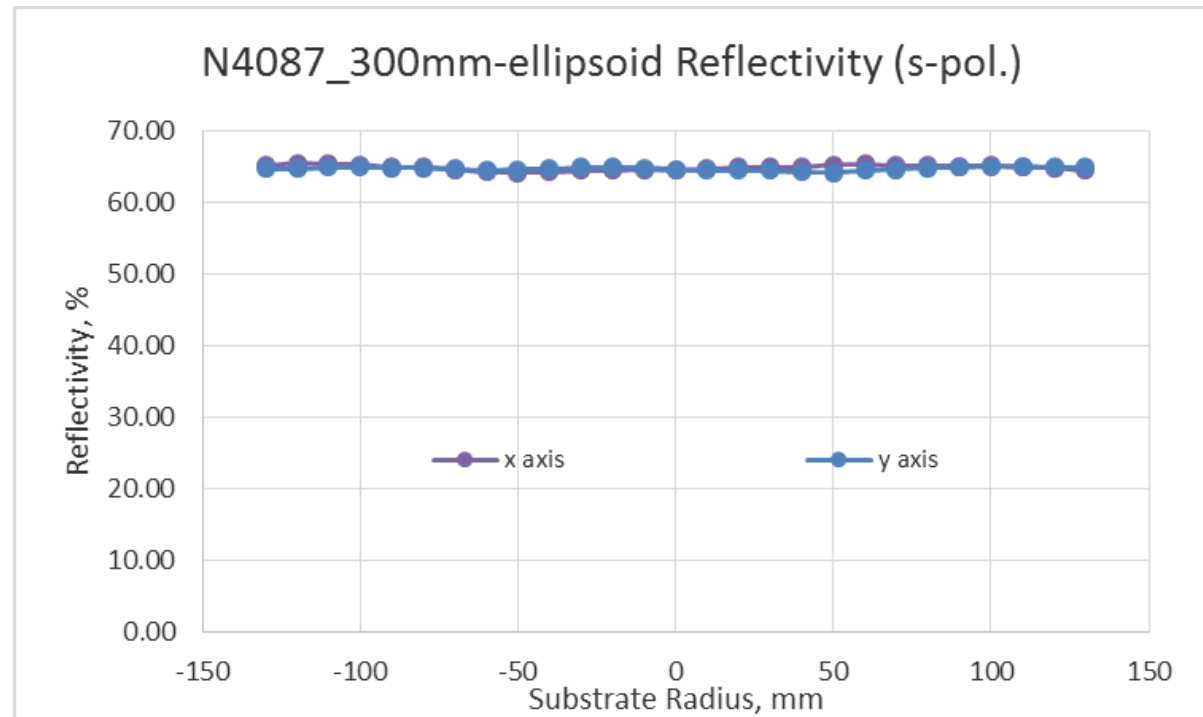
- $\lambda = (13.500 \pm 0.070) \text{ nm}$
- within specification of
- $\lambda = (13.500 \pm 0.125) \text{ nm}$



Characterization of reflective properties

Reflectivity (s-polarized)

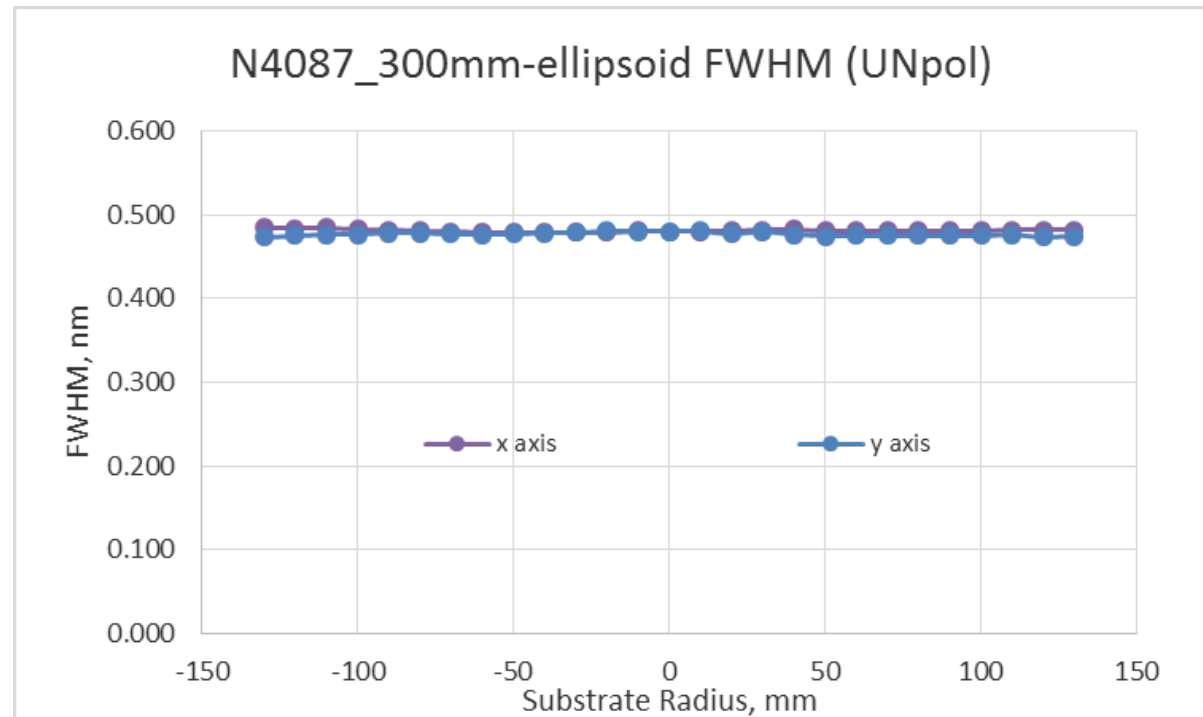
- $64.07 \% < R_{s-pol} < 65.37 \%$
 $R_{s-pol\ avg} = 64.71 \%$
→ within specification of
 $R_{s-pol} > 60.00 \%$
- standard deviation $\sigma = 0.316 \%$
(of *all* values of radii $r \leq 130$ mm)
→ within specification of
 $\sigma < 1.000 \%$



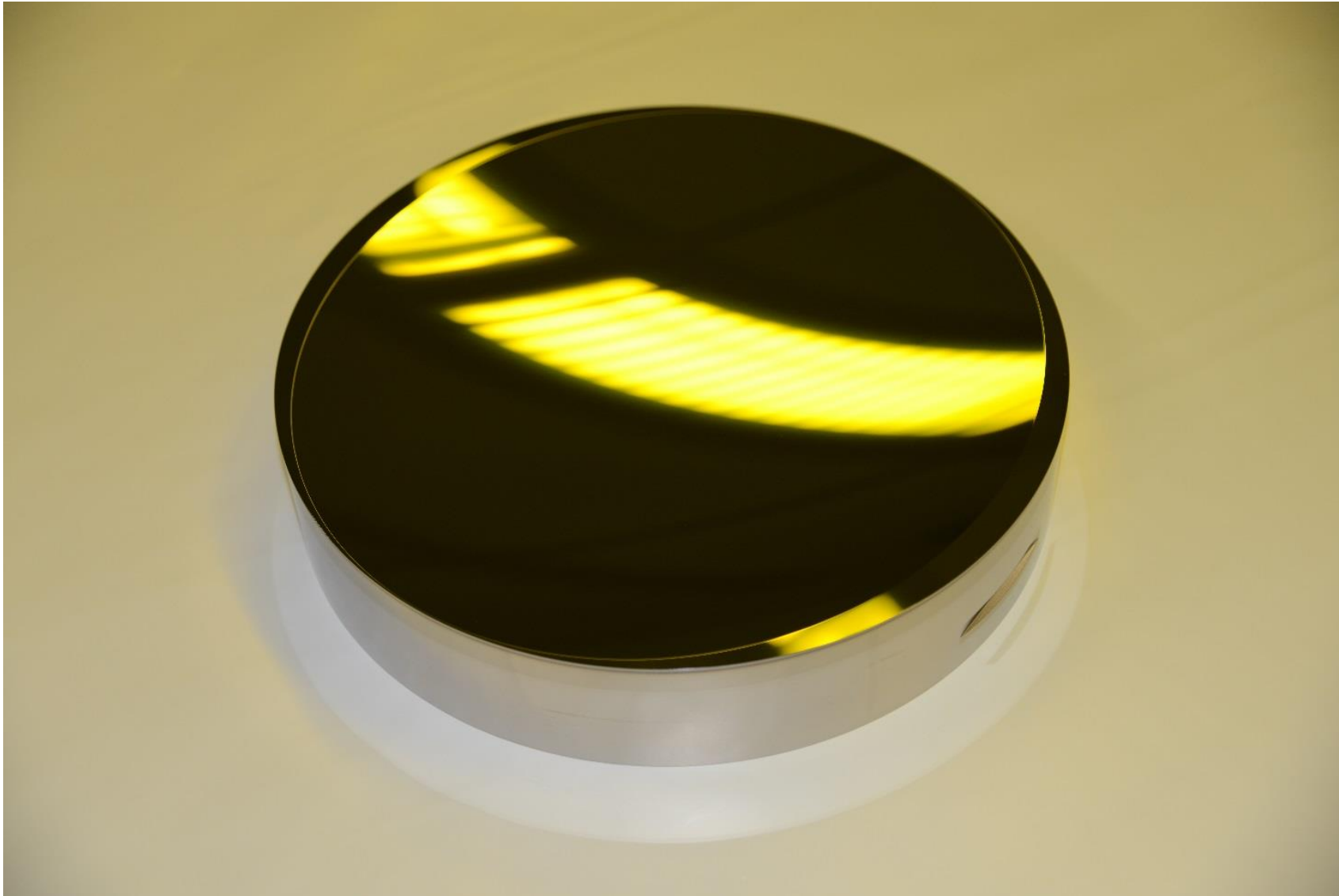
Characterization of reflective properties

FWHM (unpolarized)

- $0.473 \text{ nm} < \text{FWHM} < 0.484 \text{ nm}$
- within specification of
 $\text{FWHM} < 0.500 \text{ nm}$



Delivered in August 2014!



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Summary

- Development of customized EUV multilayer optics from 1 nm to 100 nm
- New reflectance level for EUVL: $R = 70.12\%$ @ 13.49 nm
- Development of metal multilayer collector mirror for DPP EUV metrology sources

Acknowledgements

- **EUV tool development team @ Bruker ASC:**

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Thank you.

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